A Visualization Model Supporting an Efficient Context Resumption in Collaboration Environments

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Abstract. Activity awareness support is a key feature for helping people to resume the state of their collaborations when switching among different tasks.
This paper proposes a visualization model supporting an incremental access to information, from an overview of the state of the user's activity contexts to the details about the events occurred in each of them. The higher visualization layer is represented as a tag cloud and provides a general view of the degree of activity occurred in each context. The other levels are projections on the event history focused on specific perspectives; e.g., general collaboration, task or actor.
A user study showed that our visualization model outperforms standard awareness spaces which provide a direct access to awareness events because it enables users to retrieve the relevant information quicker and more precisely.

Keywords: activity awareness support, collaboration environments, information visualization, Web 2.0.

1 Introduction

Activity awareness support (i.e., the provision of information about the events occurred in the users' collaborations) is a key feature for helping people to resume the state of their tasks when switching from one to the other. However, it involves notifying the user about many different types of information concerning their collaborators, the artifacts to be manipulated, the actions performed by others and the pending tasks. Thus, a major issue is that of protecting the user from data overload. Indeed, the awareness spaces offered by most collaboration environments present large event histories which challenge the user when searching for information.

In [1] it is discussed that the low-level events describing the operations performed on shared artifacts are not enough to help users to synchronize with each other. For that purpose, users also need to get a picture of the evolution of their collaboration contexts. Therefore, the *activity awareness* concept is introduced to represent "the awareness of project work that supports group performance in complex tasks".

The work described in this paper is aimed at evaluating whether offering an incremental access to awareness information in a collaboration environment can help the user to resume the state of her/his activity contexts. We are interested in reducing the size of the information space by enabling the user to visualize awareness events from

perspectives reflecting different information needs. In particular, we propose a model for the visualization of information which summarizes the state of the user's activity contexts and from which the details of the occurred events can be easily retrieved. In this way, the user can quickly decide whether some contexts deserve to be inspected in detail. Our model is organized at different levels:

a) The upper level, represented as a tag cloud (the Awareness Cloud), provides a general view of the degree of activity occurred in the user's collaborations.
b) The middle level supports the dynamic generation of projections on the set of awareness events focused on specific information needs.
c) The lower level offers a complete view of awareness information.

We conducted an experiment with end users to assess how people interacted with these views. The results revealed that our visualization model outperforms standard awareness spaces which provide a direct access to information because it enables users to retrieve the relevant data quicker and more precisely.

The rest of this paper is organized as follows: Section 2 introduces activity awareness and describes the context-dependent management of information underlying our proposal. Section 3 presents our visualization model. Section 4 describes the user study we carried out and discusses its results. Section 5 compares our work to the related one and Section 6 concludes the paper.

2 Background

In a collaboration environment, many types of events can be captured and visualized, that describe the actions performed by the user or by her/his collaborators while they use the integrated business services. The provision of awareness information about the users' actions is challenging: as reported in [2] and [3], people are observed to frequently switch among their tasks with a consequent effort in resuming the state of the context they enter. However, a compromise has to be reached between helping somebody to catch up with the surrounding environment and overloading her/him with large amounts of details about the events occurred in there.

The information overload risk was evident in former collaboration environments; e.g., see [4]. However, nowadays it is even more problematic, as private and corporate users are increasingly using online services to carry out their activities by exploiting the ubiquitous environment offered by the Internet [5, 6]. Therefore, the number of private and shared activity contexts to be handled, and the amount of awareness information to deal with, are much larger than before.

We aim at developing a visualization model that helps the user to browse such large amount of data and helps her/him to quickly find the relevant information. For this purpose, we assume that the awareness events describing the actions performed in the collaboration environment are classified in activity contexts, so that they can be managed in a structured awareness space reflecting the user's collaborations and private activities. Therefore, before describing our proposal, it is worth providing a background on the context-dependent management model we build on.

The research on ubiquitous systems provides various definitions of context. Dey and Abowd define it as "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves" [12]. In [13], Dey and Abowd's definition is refined by specifying possible categories of context information such as individuality, activity, location, time and relations. For the context-dependent management of awareness information we focus on two dimensions introduced in [13]: the first one is the activity context, i.e., what the user is doing and how this relates to her/his objectives and commitments. The second one is the specification of the relational contexts in which the user engages and of the related artifacts. As described in [14, 15], we model the following types of contexts:

- *Collaboration sphere*. This is a thematic group, similar to a virtual community, used to keep in touch with each other. For instance, a "family" sphere could be defined to keep track of the communication with the user's relatives.
- *Activity frame*. This is a more or less structured project which a user can define to collect artifacts of interest around a topic and manage activities aimed at reaching a goal, possibly in collaboration with other people. For instance, an activity frame could represent a work project for the preparation of a conference paper.
- *Task*. This is used to specify and carry out the execution of an activity, possibly shared with other users; e.g., writing a section of the above mentioned paper. A task may include artifacts to be manipulated and can have a deadline. Tasks are created within activity frames and can be related to each other in partial order relations to coordinate the execution of complex activities.

For each type of context we assume that the group of involved users is specified, as well as the artifacts to be accessed (documents, etc.).

Even though several business services generate events about the actions performed by their users, they typically cannot associate them to their execution contexts because they do not model this type of information. For instance, document sharing applications generate events describing different types of operations, such as the fact that somebody has uploaded/removed/shared a document. However, such events are not related to the task which the actor was performing when they were generated. In order to present events in a view structured on the basis of the user's collaborations, an awareness support tool has to analyze and pre-process them. A framework is described in [14] and [15] for the development of user-centered service clouds supporting an explicit management of contexts and the appropriate classification of awareness events. The visualization model proposed in this paper builds on that architecture but could be applied to a different one, as long as it guarantees the association of events to actors and contexts.

3 Incremental Visualization of Awareness Information

We propose to offer the user a view on awareness information which can be focused on the recent past and on specific needs. Our visualization model presents information at different levels: overview of the user's collaborations, events related to a collaboration sphere, activity frame or task, and long-term event history. Moreover, as users may want

to monitor the activities carried out by other people, our model supports the presentation of events concerning the user's collaborators.

3.1 Higher Layer: Awareness Cloud

Fig. 1. Higher visualization layer: Awareness Cloud of a user of a collaboration environment (utntest1@gmail.com).

The higher presentation layer provides the user with an overview on the state of her/his activity contexts, possibly focused on a specific time interval, e.g., during the last two days or after the last "catch up" with such contexts. The design of this layer has been driven by two main requirements:

1. Limiting the overload effect on the user. In fact, if the user engages in many different activities, the number of contexts whose state is visualized can be rather large.
2. Helping the user to quickly identify the contexts deserving attention.

At the current development stage, we decided to synthesize the state of each activity context as the relative number of awareness events occurred in the selected time interval. We chose this type of information as a starting point because it supports the identification of the contexts that evolved most quickly in the recent past. However, other data might be integrated in order to provide a richer abstraction on such a state; e.g., the occurrence of high-priority events.

The second requirement lead us to select the tag cloud visualization model for the presentation of information at this level because, especially for open-ended searches, tags are known for immediately evidencing the most relevant contents, thanks to their large visual differences from other elements; see [16, 17].

We thus designed this layer as an Awareness Cloud showing the degree of activity occurred in the user's private and collaboration contexts. The nodes of the cloud represent activity contexts and actors in order to enable the user to monitor the state of her/his collaborations from different viewpoints: (i) how many events occurred in a context; (ii) how active was an actor in the collaborations shared with the user. As shown in Figure 1, the Awareness Cloud for a user U (utntest1@gmail.com) is presented in a web page. The top of the page supports the configuration of the cloud:

- The form at the right (Month, Day, Year) can be used to specify the starting date of the Awareness Cloud. If such form is filled in, the event history starting from the selected date until the current time is used to generate the cloud.
- The "CATCH UP!" button at the left enables the user to refresh the cloud by setting the starting time to the current time. If the user does not specify the starting date, the cloud is generated using the time of the last catch up.

The lower portion of the page displays information about the user's activity contexts in the selected time interval.

- The nodes represent four types of entities: *user* nodes are associated to U's collaborators; *Collaboration sphere*, *activity frame* and *task* nodes are respectively associated to the user's collaboration spheres, activity frames and tasks. For instance, in the sample Awareness Cloud of Figure 1, CLAUDIO is a user node and LAVORO A (work A) represents a collaboration sphere. In order to help the user to distinguish user nodes from context nodes, the former are in italics. In contrast, all types of context nodes have the same font style because the cloud abstracts from hierarchical details concerning the user's activities (collaboration sphere including activity frames, which in turn include tasks).
- The relative size of nodes represents the degree of activity in the selected time interval and depends on the number of associated awareness events that have been collected in the collaboration environment. Notice that user nodes visualize the degree of activity of the represented users *within U's activity contexts* because the operations performed in other contexts must not be disclosed.

For each user, a dynamic awareness cloud is generated, which reflects the activity contexts (s)he engages in and the selected time interval.

In order to facilitate the inspection of details, the nodes of the cloud are direct access points to the awareness information presented in the middle layer. Each node is linked to a view which shows the related awareness events; e.g., all the events concerning PRENOTARE ALBERGO (book hotel) since the last catch up.

The Awareness Cloud includes a maximum number of 40 elements to be visualized at each time because, as discussed in [17], a cloud with too many tags can be puzzling and hard to read. Should more than 40 elements be eligible for visualization, those with least elements would be dropped. The user can however personalize the cloud by suppressing nodes (s)he is not interested in. Moreover, we are extending the cloud generation model with the specification of high-priority nodes, associated to users and/or contexts to be monitored with particular attention. Such nodes must not be dropped from the cloud and will be depicted in a different color for easy identification.

Fig. 2. Middle visualization layer: Detailed view on awareness information focused on context "LAVORO A".

3.2 Middle Layer: Hierarchical Views on Awareness Information

The middle layer of our visualization model enables the user to view the detailed awareness information from different perspectives: i.e., the events concerning a particular activity context or collaborator, in a restricted time interval. Each view is a web page generated by taking into account the context represented by its source node in the Awareness Cloud and the time interval selected for the generation of the cloud. Specifically:

- A view linked from a user node displays the events describing the actions performed by the represented actor in the activity contexts shared with the current user.
- A view linked from a context node displays the events occurred in that context.

Figure 2 shows the view associated to node LAVORO A of the Awareness Cloud: events can be sorted by date, activity context and task, or by actor (if such information is provided by business services).

As activity contexts can be nested, the middle visualization layer supports a hierarchical exploration of awareness information that enables the user to visualize details about activity contexts at different granularity levels. For instance, as the LAVORO A context includes the PROGETTO EUROPEO and CONFERENZA OLTREOCEANO activity frames, its view includes two links pointing to views focused on such contexts; see the top-left portion of the page.

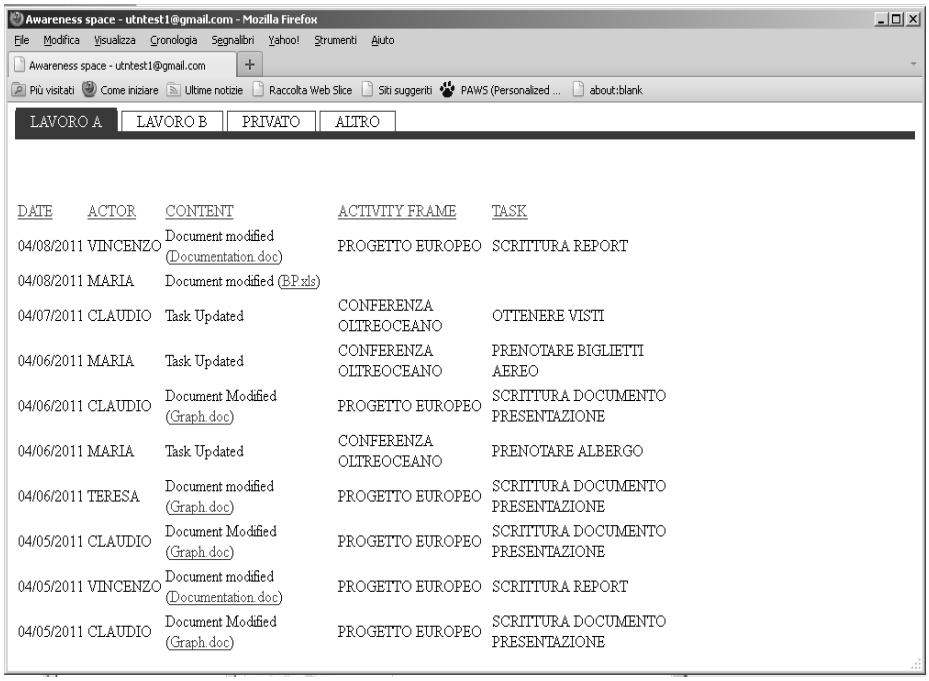

Fig. 3. Lower visualization layer: Awareness space of user utntest1@gmail.com, focused on tab LAVORO A.

The views of the middle visualization layer also include a “GO TO AWARENESS SPACE” button (see the top-right portion of Figure 2) which can be used to access the awareness space of the collaboration environment, i.e., the lower visualization level.

3.3 Lower Layer: Context-dependent Awareness Space

The lower level of our model is the awareness space of the collaboration environment, which presents the long-term event history concerning the user’s activity contexts. In order to support the navigation of such information, this space offers a different tab for each of her/his collaboration spheres. Moreover, within a tab events can be sorted by date, actor, content and activity context. Figure 3 shows a tab of the awareness space for the LAVORO A collaboration sphere of user utntest1@gmail.com. The event list shown in this page is longer than the one reported in Figure 2 because the awareness space is not subject to time constraints.

3.4 Technical Details

We developed a prototype demonstrating our visualization model in a collaboration environment based on the Personal Cloud Platform (PCP) [14]. The PCP enables the user to specify her/his collaboration spheres. Moreover, it includes a Collaborative Task

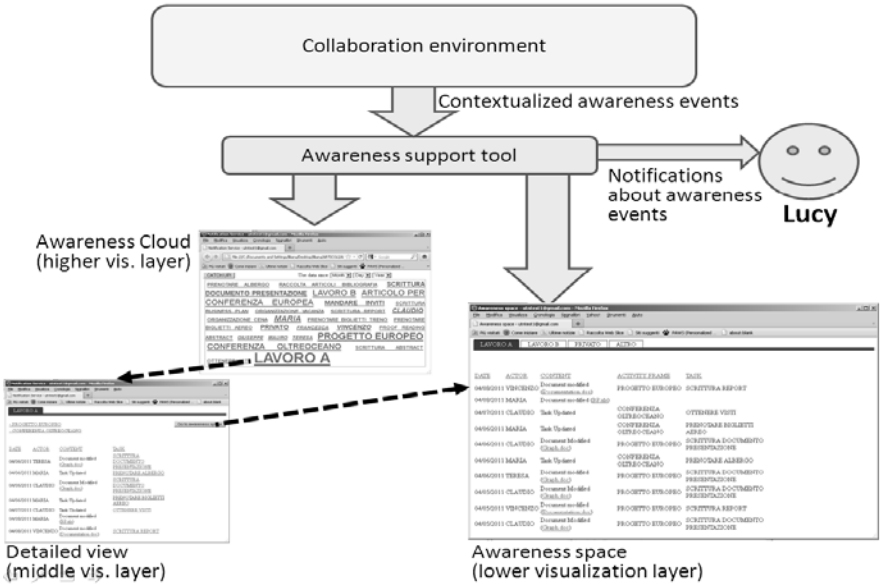

Fig. 4. Awareness information management.

Manager (CTM, [15]), integrated with business services, which enables the user to handle activity frames and tasks and to perform operations within specific activity contexts, so that the resulting events can be appropriately classified.

Figure 4 shows the flow of information concerning awareness management: the events captured by the collaboration environment (and associated to the user's activity contexts) are received by an awareness support tool which generates synchronous notifications for the user (see [18]) and manages the incremental access to events in the awareness space. The figure highlights the generation of the views on awareness information and the links between them.

4 Tests

4.1 Description

We conducted an experiment to evaluate the impact of the incremental access to awareness information on users' experience. We wanted to test a hypothesized causal relationship between the introduction of the Awareness Cloud on top of an awareness space structured on the basis of the user's activity contexts (henceforth, context-aware awareness space) and people's performance during a task. Our research question was *"Does an incremental access to awareness information, based on a context-dependent tag cloud, modify the level of users' performance with an activity awareness space?"*. If the answer is positive, which case can give best results?

Hypothesis (Ha): The introduction of a custom tag cloud supporting the incremental access to a context-dependent activity awareness space improves users' performance on an awareness information seeking task, in terms of execution time and number of errors.

16 volunteers participated in this experiment (10 men and 6 women). They were students or staff of the University of Torino and performed the test for free, without any reward. The experiment had a single-factor, between-subjects design. Two treatments were applied: the experimental one consisted in a context-dependent activity awareness space enhanced with an Awareness Cloud and the middle visualization layer; the base-case was a context-dependent awareness space (lower visualization layer alone).

Each treatment condition was considered as an independent variable. Participants' performance was considered as a dependent variable and was calculated considering two objective measures: number of committed errors and time needed to complete the task. Participants were divided into two groups of eight people and each group received a single treatment in order to prevent side-effects such as practice and fatigue.

Before starting the task, users had to answer a questionnaire aimed at measuring their level of practice with collaborative applications at the workplace and in private life. Each user could choose between four non-decreasing levels of practice, ranging from 0 to 3. Results showed no significant difference among users in the two environments.

The experimental task was designed as an information recovering and comprehension one, simulating a typical, asynchronous reception of awareness information in a collaboration environment. All users were briefed about their scenario before the beginning of the task: as participants of three different collaboration groups, they had received awareness information (13 new events) regarding other users' activities, that was still to be read. Such information was collected in the awareness space, which organized events on the basis of its originating activity context. Each user was given information about the nature of their (simulated) collaborations, such as names of collaboration groups, projects, tasks and involved users. Such instructions were available to participants as a reference during the experiment. Each participant was engaged in testing activity for a period of about 15 minutes.

Users were then asked to browse the awareness space at their disposal in order to answer the following six questions:

1. Which user completed the largest number of elementary operations regarding context "LAVORO A"?
2. How many tasks progressed (in terms of completed operations) within context "LAVORO B"?
3. Which user completed the last operation on task "SCRITTURA DOCUMENTO PRESENTAZIONE" in project "PROGETTO EUROPEO", context "LAVORO A"?
4. In which context was the largest number of operations carried out?
5. Please write contexts, projects and tasks where user "MARIA" completed one or more operations.
6. Which users carried out at least one operation regarding the tasks of project "ORGANIZZAZIONE CENA", which belongs to context "PRIVATO"?

Participants performed the task on a PC laptop (a Dell Latitude E6400 equipped with Windows XP), with the built-in monitor as the display (14.1-in LCD, 1280x800

pixel resolution). Sessions were clocked by the experimenter, who annotated all interesting actions and comments by the users while sitting at some distance from them.

4.2 Results and Discussion

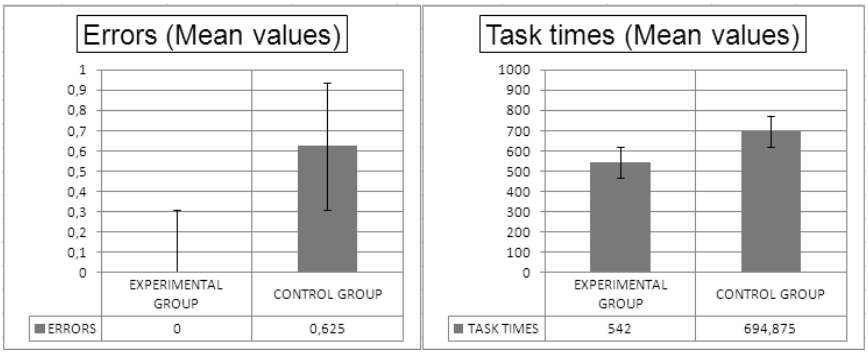

Fig. 5. Test results.

Figure 5 shows the results of the user tests. The figure is split in two parts which show mean values for the two treatments: the values are referred to the number of errors and execution times (in seconds) respectively, and are defined on the y-axes; the x-axes identify the treatment group. Error bars represent the standard error estimates.

We used an unpaired Welch's t-test, which does not assume equal variances, to analyze collected data. An alpha level of 0.05 was used to make decisions of significance. We found a significant effect either for number of errors ($t = -2.38$, $p = 0.049 < 0.05$) and for execution times ($t=-3.15$, $p = 0.011$), that lead us accept hypothesis Ha.

In the second questionnaire we asked participants to evaluate their own experience with the user interface they operated with. Each user could choose between seven non-decreasing levels of satisfaction, ranging from 0 to 6. The experimental group expressed a mean value of 5,81 for their user interface (st.dev = 0,55), while the mean value for the control group was 5,31 (st.dev = 1,02).

The results of this experiment revealed that the incremental access to awareness information significantly improved users' performance, in terms of times of execution and number of errors. First-hand observations of participants behavior lead us to grasp two aspects that may explain these results:

- The Awareness Cloud proved itself as very easy to understand and to use, and showed a good level of integration with the awareness space. Indeed, the users of the experimental group were left free to choose whether to adopt it or not, but every one of them opted for its use since the first question.
- The Awareness Cloud allowed users to express fast and precise queries by clicking on the desired nodes, with a user interface that was valued as "practical, good and

interesting". Browsing the awareness space in isolation did not prove itself as immediate and error-free: users of the control group who did not commit errors spent more time doing their tasks, probably verifying their answers.

Users indicated as a major drawback of the Awareness Cloud the fact that it made hard to spot nodes with low density of events: while it could be faster to identify high density elements, those written with the smallest font, such as low-activity tasks, might get lost among the crowd. This aspect is typical of a tag cloud [17] but could be addressed by supporting a personalized configuration of the cloud, based on the user's interests. We plan to enable the user to configure the Awareness Cloud by specifying which elements (s)he wants to monitor with most attention.

5 Related Work

The incremental access to awareness information differentiates our work from standard groupware and project management tools such as BSCW [7], CANS [10], ActiveCollab [8] and TeamWox [9], which organize information on the sole basis of its reference workspace/group/directory.

In some collaboration environments, the visualization of the degree of activity within a group, or shared workspace, is proposed as a synthetic form of awareness provision. For instance, in [4] AwarenessMaps are proposed to provide the members of shared workspaces with an overview of users and documents: "the PeopleMap shows an array of pictures of active users fading out over time; and the DocumentMap provides a schematic overview of the structure of a shared workspace and indicates recent changes." Moreover, in [19] is introduced a pictorial representation of incoming e-mails (Info-Lotus) divided in groups and sub-groups to represent conversation threads. Furthermore, in [11] is proposed a radar view of awareness events; however, information is only classified by source application. Thus, the awareness spaces might be very large and challenge the user with too much data.

Our proposal improves activity awareness support by visualizing information at different granularity and abstraction levels. The *granularity* aspect concerns the generality of the activity context to be considered and is motivated by the fact that people engage in different types of collaborations, such as thematic groups (e.g., small or large virtual communities), more or less structured projects, and specific tasks. The *abstraction* aspect enables the user to receive a summary of the state of her/his activity contexts, from which (s)he can select the contexts to be inspected in detail.

Recently, the research on collaboration in online communities has focused on activity awareness in order to inform users about who is active in the topics of interest of the community and which kind of contribution has been provided. For instance, Vassileva and Sun propose a "star" view of users, aimed at showing their degree of activity in the community [20]. Moreover, in [21] a visualization of activity awareness in CiteULike is proposed, which exploits radial time bands to show the time period during which the user/group activity (or the activity on a topic) has occurred. Our approach differs from such works because, besides modeling individual users and groups, we model the user's activity contexts. Therefore, the visualization we propose enables the user to assess the state of general collaborations as well as to focus on very specific tasks. This feature

makes our visualization model suitable for integration in collaboration environments, where users can engage in shared activities having different complexity levels.

6 Conclusions

This paper described a visualization model supporting the incremental access to activity awareness information in a collaboration environment. Our model presents information at different levels of detail in order to provide the user with a general view on what has recently happened in her/his collaborations and enable the retrieval of detailed information on specific activity contexts. The goal is that of assisting users in resuming the state of their collaborations. A user study showed that our model outperforms standard awareness spaces which provide a direct access to awareness events because it enables people to retrieve the relevant information quicker and more precisely.

Our proposal is the first step towards the development of an adaptive awareness support service offering a personalized view of information. At the current stage, our model provides the user with a context-dependent view on awareness information which reflects her/his activities, projects and collaborations. In our future work, we plan to extend it in order to take further aspects into account: e.g., the priority of the user's contexts could be used to customize the incremental access to information (e.g., by putting high-priority contexts and actors in evidence so that their evolution can be monitored). Moreover, not only the degree of activity occurring in the user's contexts, but also the importance of the events, could be considered for presentation purposes. Furthermore, the user's interests across activity spaces could be tracked along time in order to support both a manual specification of interests and a dynamic adaptation of the visualization model on the basis of the user's behavior; e.g., see [22] for a similar approach applied to notification management. Finally, our visualization model should be extended to support the adaptation to heterogeneous devices, including smart phones, because the current version is designed for medium size screens, such as those of laptops and desktop computers.

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